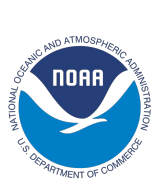# UFS R2O Project

AGU Town Hall: 02 December 2020

NOAA NWS & OAR

NWS STI-Modeling: Dorothy Koch, Yan Xue, Maoyi Huang
[OAR WPO: Daniel Melendez, Chandra Kondragunta]

EMC, PSL,
GSL, CSL,
NSSL, ARL,
NESDIS

The UFS-R2O Project

- **Unified Forecast System (UFS)** is a community-based, coupled comprehensive Earth modeling system, to support the Weather enterprise and to serve as the source for NOAA's operational prediction applications.
- **UFS Research to Operations (R2O)**: Developing next-generation global and regional forecast systems for NOAA, to go into operations by FY24
- **UFS-R2O Project** is NOAA's largest investment in the UFS, $13M/yr for 2 years
- Supported and managed by NOAA's operational (NWS) and research (OAR) line offices
- Project team has over 100 scientists from NOAA operational centers, NOAA research laboratories, NCAR, JCSDA, DTC, Universities

The wider UFS context

The **UFS-R2O Project** is a subset of the **UFS** that is funded by NOAA and focuses on the transfer of innovations into operations (lower part of the R2O "funnel").

"Earth Prediction Innovation Center" (EPIC) is a new NOAA initiative that will be providing infrastructure and user support.

UFS

Basic Research

EPIC

UFS-R2O Project

Operations

Transition to Operations

Operational forecast systems

3
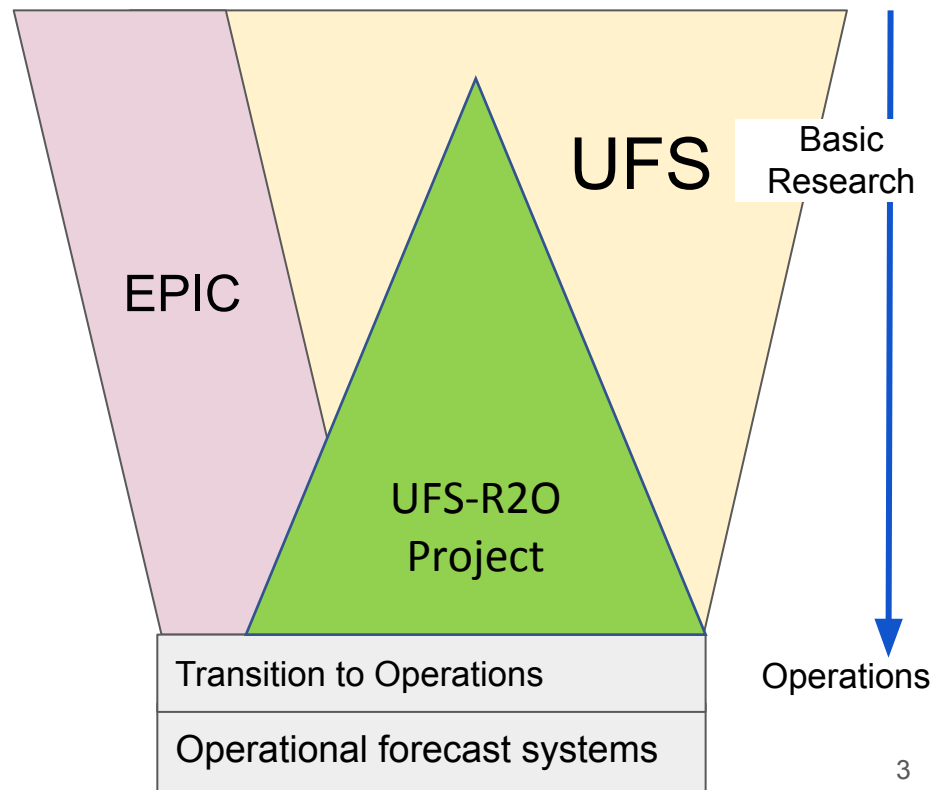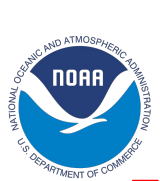
Two UFS Town Halls
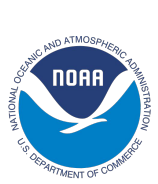
- **The UFS-R2O Project Town Hall**
  - Perspectives on the next-generation UFS forecast system developments
  - How to get involved in developing or analyzing these next-generation systems in collaboration with UFS R2O Project

- **The UFS Community Town Hall (December 10, 10-11am ET, Tolman et al)**
  - Broader UFS perspective
  - How to get involved in the UFS
  - How to download and work with the released UFS systems

Agenda today:

1. **Project Lead (Vijay Tallapragada) will present the project (20 minutes)**
   a. Background
   b. Early results: Global - Regional - Infrastructure

2. **How to get involved & opportunity to ask us questions (25 minutes)**

UFS-R2O Project Inspiration

- **From UCAR Modeling Advisory Committee (2018 report):**
  - **NOAA must be "all-in" in developing and deploying a unified community model, with a unified collaborative strategy**
  - **NOAA Modeling & DA needs to be integrated and collectively managed**
- **NGGPS selection of FV3 dynamical atmospheric core**
- **Establishment of Unified Forecast System (UFS)**
- **From EPIC Vision and Mission:**
  - **Accelerate scientific research and modeling contributions through continuous and sustained community engagement** to produce the most accurate and reliable operational modeling system in the world.
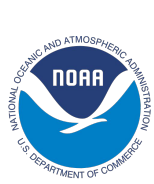
A new way of doing business!

- **An experiment to carry out R&D in a collaborative project within constraints imposed by operational imperatives and public release timelines**

- **Engagement within NOAA (NWS-OAR-NESDIS-NOS) and wider UFS community, with coordinated funding from both NWS & OAR.**

- **Interested/engaged/willing participants from inside and outside NOAA under a single management framework**

- **Project with a 5-year vision, first 2 years of deliverables defined**

Scientific Priorities

Motivated by forecast priorities collected from stakeholders/testbeds

- **Reduce coupled model biases**
- Improve representation of **key modes of variability** (including MJO)
- Optimally combine Earth system observations and model forecasts using an **advanced data assimilation system to initialize coupled ensembles** (land-ocean-sea ice-atmosphere-aerosols).
- Develop a **convection-allowing ensemble forecast capability** for short-range prediction of severe weather and hurricanes.
- Improve **initialization at all scales** (convective to global), through **improved use of observations and advances in data assimilation algorithms**.
- Improve **quantification of model uncertainty in ensembles**, especially near model component interfaces.
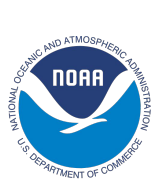
UFS-R2O Project History

- **Summer 2019:**
  - EPIC community meeting, begin to organize the UFS community in preparation for EPIC
- **Fall 2019:**
  - NWS and OAR program managers agree to coordinate and commit resources
  - Program office invites ideas from UFS community and launches project organization
- **Winter 2019-2020:**
  - Program office invites proposal and organizes external peer review
  - Final proposal submitted (>100 pp)
- **March 12-13, 2020:**
  - Face-to-face peer-review in Silver Spring, MD
- **April-May 2020**:
  - Project descoped and supported:
    - $13M/yr: NWS-OSTI $10M and OAR-EPIC & JTTI $3M
- **July 9-10, 2020**:
  - Project kick-off meeting, 200+ attended
- **October 1, 2020**:
  - First Quarterly Program Review

Participation to the UFS-R2O Kick-off meeting
Total number: 219

NOAA-Fed
23.7%

Non-NOAA
15.7%

NOAA-Aff
60.6%
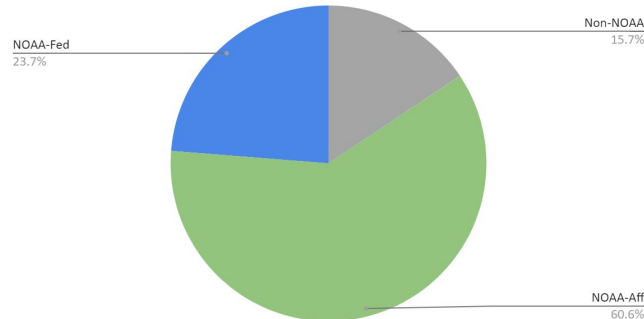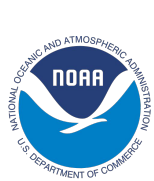
Project Goals – Years 1-2

- **First 2 major operational systems, global and regional, to be developed jointly between NOAA and the community!**
  - Initially targeting GFSv17/GEFSv13/HREFv3/RRFSv1/HAFSv1
- **Fully coupled (L-O-SI-A-W-Ae) global ensemble prediction system, including coupled DA, ready for pre-operational testing and suitable for community research use**
  - Addressing science priorities and leading to operational forecast improvements in priority areas
  - Reanalysis/reforecast capability for calibration/bias correction (production in years 3-4)
  - Public releases of coupled Medium-Range weather/S2S application
  - Public releases of JEDI data assimilation framework
- **Regional rapid refresh (1-hour cadence) ensemble forecast system for convection-allowing scales ready for pre-operational testing**
  - Public release of Short-Range weather application
- **Start to sunset existing global and mesoscale prediction systems in collaboration with academic and forecast communities**
  - Forecast system unification – simplification of operational product suite
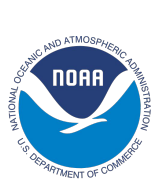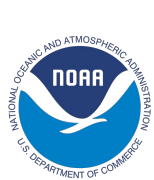
Longer Term (5 Year) Vision

- **Advanced coupled DA capabilities**
  - Allow observations of one component (e.g. atmosphere) to update all components.
- **JEDI for initialization of all forecast systems**
  - Advanced ensemble, hybrid and 4D-Var algorithms, enhanced use of satellite radiances.
- **Next-gen moist physics suite for the atmosphere, unified for CAM to global**
- **CAM-resolution inline air quality prediction and direct aerosol feedback**
- **Warn on Forecast system for severe weather outbreaks & flash flooding events**
- **Hurricane Analysis & Forecast System (HAFS) with multiple moving nests**
- **New applications integrated into UFS:**
  - Coastal inundation, storm surge
  - Surface hydrology
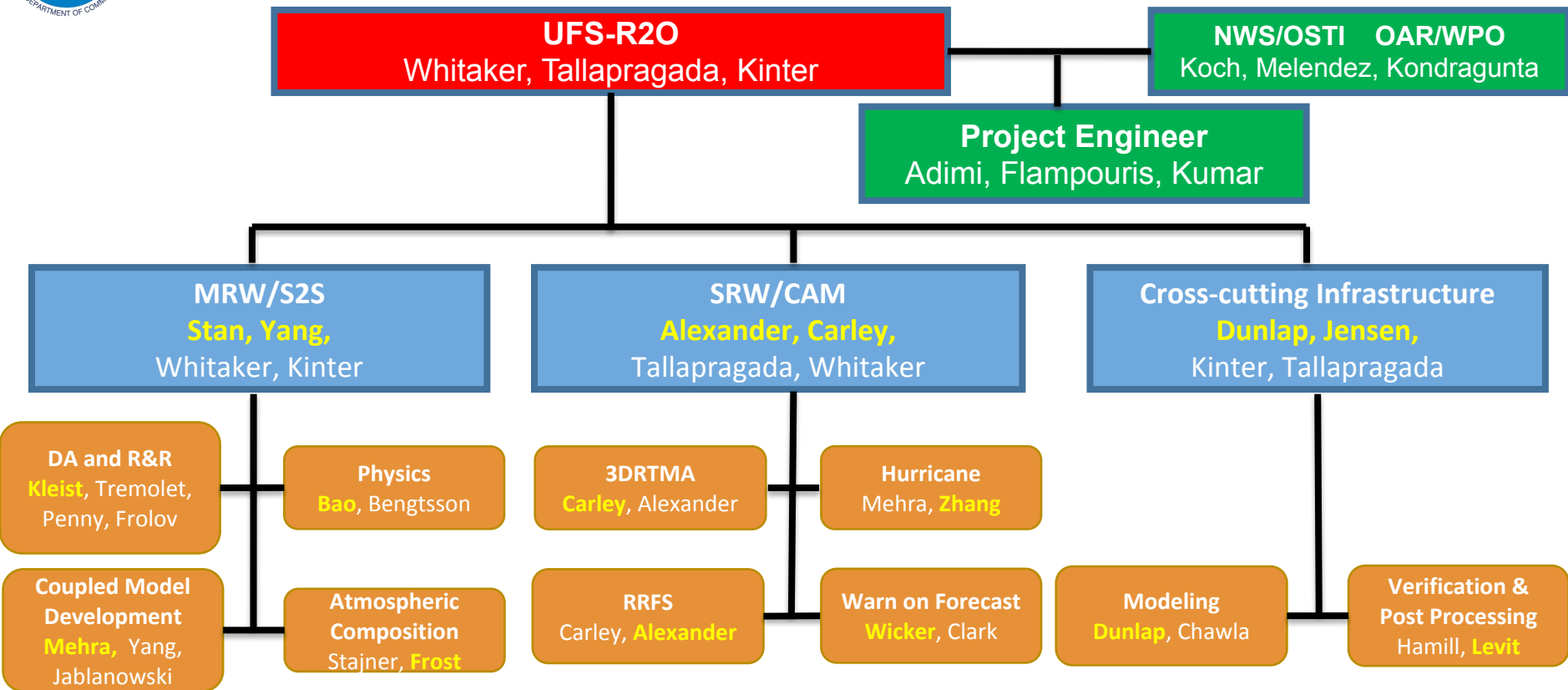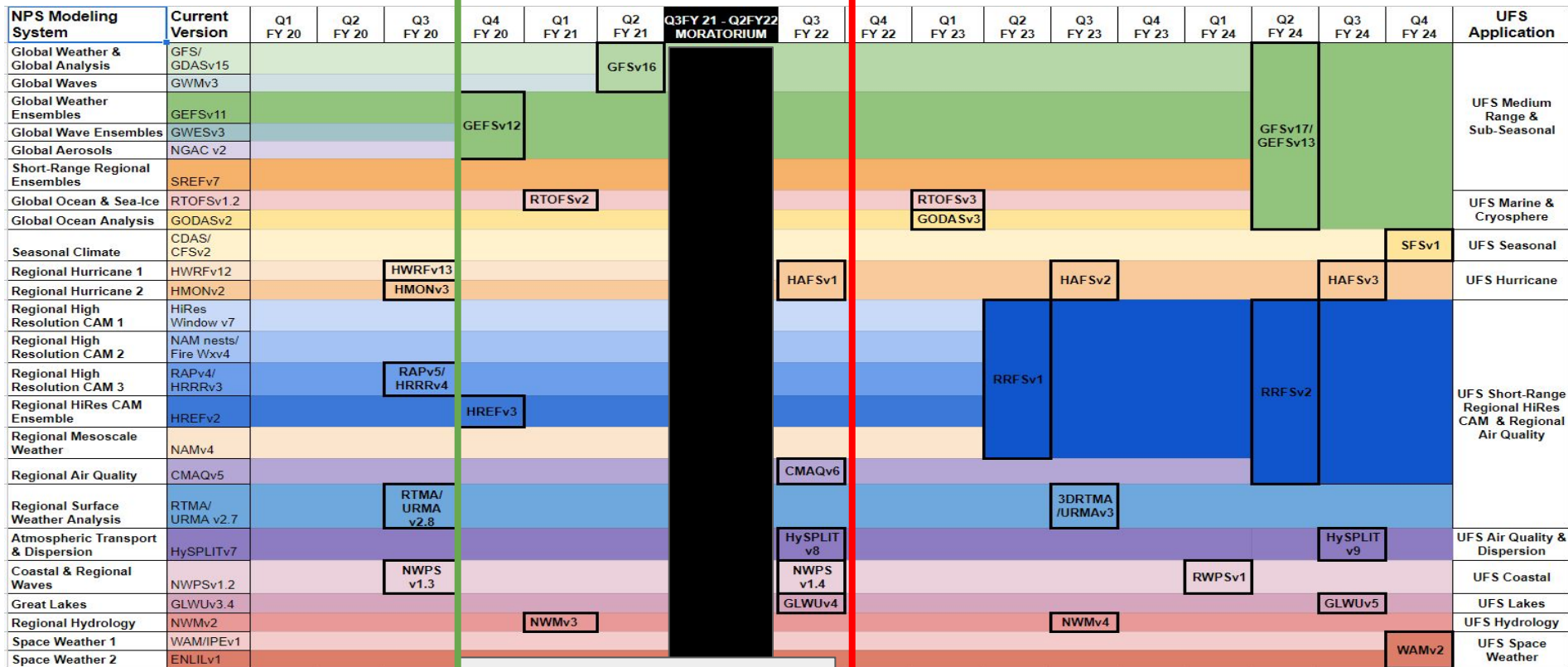 - Space-weather prediction
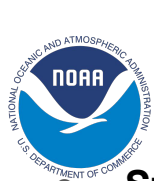
Guiting Principles

- **Strong leadership accountable to funding organizations and responsive to community**
- **Coordinated development of shared modelling and data assimilation infrastructure and algorithms (across Earth prediction enterprise)**
  - Data assimilation: *JEDI*
  - Coupling model components: *ESMF, NUOPC, CMEPS*
  - Interoperable atmospheric sub-grid physical parameterizations: *CCPP*
  - Uniform code management policies: Git-based repositories with *Gitflow* model
  - Forecast verification framework: *MET+*
- **Increased attention to documentation and user support**
  - Coordinated with UFS Communications & Outreach Working Group
- **Increased attention to development/provision of supporting datasets for model calibration and validation**
- **Close coordination between UFS research community and NCEP/EMC to streamline and accelerate R2O**
- **Research publications in high-impact peer-reviewed journals**

UFS-R2O Project Structure

UFS-R2O
Whitaker, Tallapragada, Kinter

NWS/OSTI   OAR/WPO
Koch, Melendez, Kondragunta

Project Engineer
Adimi, Flampouris, Kumar

MRW/S2S
Stan, Yang,
Whitaker, Kinter

SRW/CAM
Alexander, Carley,
Tallapragada, Whitaker

Cross-cutting Infrastructure
Dunlap, Jensen,
Kinter, Tallapragada

DA and R&R
Kleist, Tremolet, Penny, Frolov

Physics
Bao, Bengtsson

3DRTMA
Carley, Alexander

Hurricane
Mehra, **Zhang**

Coupled Model Development
Mehra, Yang, Jablanowski

Atmospheric Composition
Stajner, **Frost**

RRFS
Carley, **Alexander**

Warn on Forecast
Wicker, Clark

Modeling
Dunlap, Chawla

Verification & Post Processing
Hamill, **Levit**

# Operational Models Consolidation Timeline

Coordination and Outreach

- **UFS-R2O coordination meetings**
  - Establish regular cadence of Project meetings
  - Coordinate and integrate these meetings with broader UFS community meetings
    - High readiness-level focus for UFS-R2O vs broader perspective of UFS
- **Briefings**
  - Series of briefings to NOAA leadership, UFS and community
- **UFS-R2O Vlab workspace for project communication - in progress**
  - Archive all documents: presentations, deliverables,..etc.
  - Meeting agendas & minutes & forums for discussions
- **Transition to Smartsheet for project management - in progress**
- **Slack**
  - Day to day technical discussions.
- **UFS-R2O website - coming soon**

UFS-R2O Project's
Early Results
Global system:
Medium-Range Weather/Subseasonal to Seasonal (MRW/S2S)

2011-10-04 12z
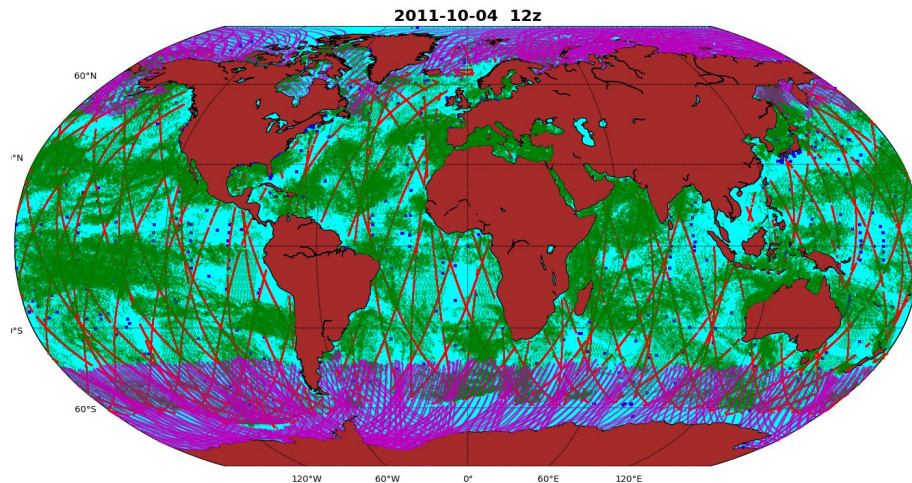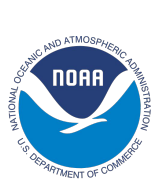
UFS MRW/S2S: Six Coupled Components

https://github.com/ufs-community/ufs-weather-model

Atmosphere

- FV3 dynamical core
- GFS Physics with GFDL microphysics
- CCPP physics driver
- C768 (~13km), 127 levels

Ocean

- MOM6 Modular Ocean Model
- ¼ degree tripolar grid, 75 hybrid levels
- OM4 Set up [Adcroft, 2019]

Waves

- WAVEWATCH III
- ½ degree regular lat/lon grid
- ST4 Physics [Ardhuin, 2010]

Ice

- CICE6 Los Alamos Sea Ice Model
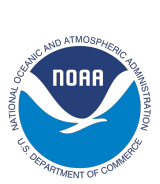- ¼ degree tripolar grid (same as ocean)

Land

- Noah-MP

Atmosphere Composition

- GOCART

Mediator

- ESMF, NUOPC, CMEPS mediator

UFS-R2O Early Results: Global MRW/S2S Application

Coupled Model Development Sub-Project:

- **UFS prototype benchmark runs**
- Evaluation priorities and S2S metrics
- Introduced land model uncertainty into ensemble members.
- Stochastic physics: Refined cellular automata code to work with current operational convection scheme (saSAS)
- 1-degree coupled model ensembles initialized with Global Ensemble Forecast System (GEFS) reanalysis ensemble in the atmosphere, and Climate Prediction Center (CPC) ice and ocean analyses for select cases.
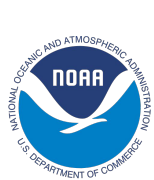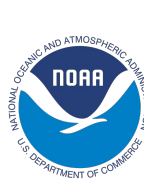
UFS Prototype Runs

	Initial Conditions					
	FV3 GFS	**MOM6**	**CICE5**	**CICE6**	**WW3**	**Mediator**
UFS_P1	CFSR	CFSR	CFSR	n/a	n/a	NEMS
UFS_P2	CFSR	**CPC 3Dvar**	CFSR	n/a	n/a	NEMS
UFS_P3.1	CFSR	CPC 3Dvar	**CPC ice analysis**	n/a	n/a	NEMS
UFS_P4	CFSR	CPC 3Dvar	CPC ice analysis	n/a	**CFSR forcings**	NEMS
UFS_P5	CFSR	CPC 3DVar	n/a	**CPC ice analysis**	CFSR forcings	**CMEPS**

- Initialize the model on the **1st** and **15th** of each month for **35 day** runs

- Model components initialized independently

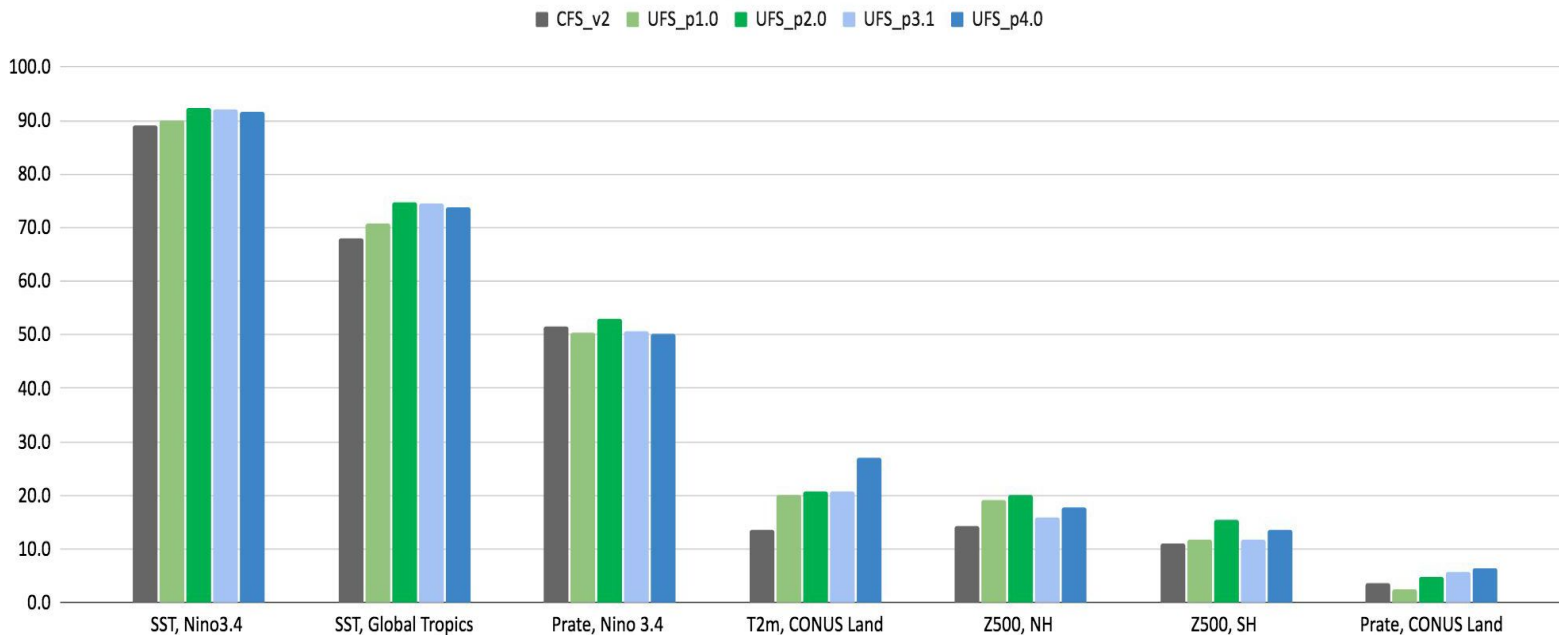- Repeat for all months over a **7 year period** (2011/2012 – 2017/2018)

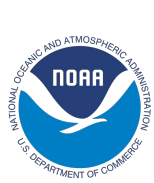- Provides a large enough sample for statistically relevant metrics

Week 3&4 AC Skill Compared with existing UFS*R2O* "Climate Forecast System" CFSv2
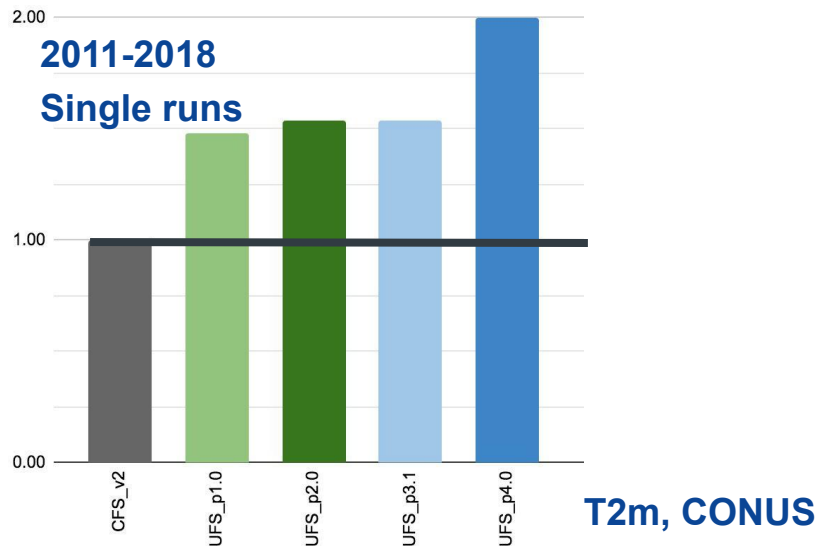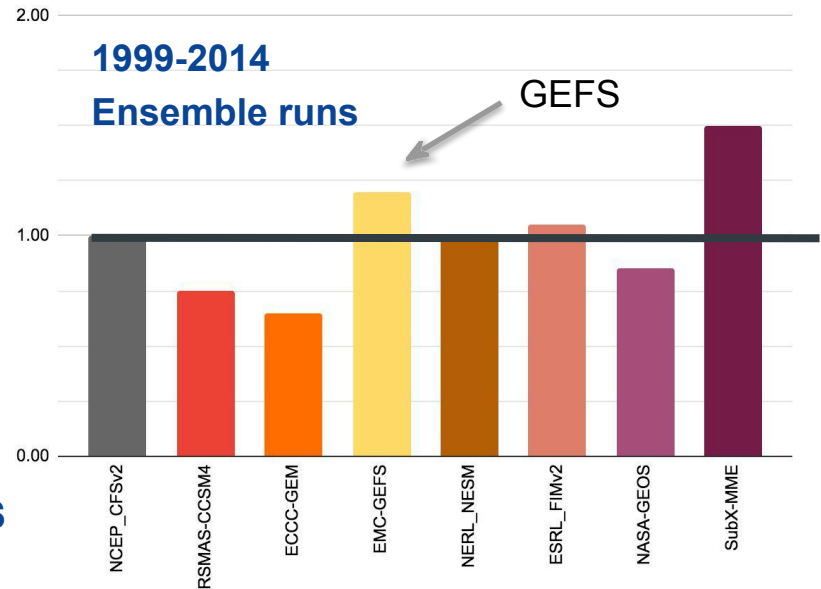
Week 3&4 AC Skill

Legend: CFS_v2, UFS_p1.0, UFS_p2.0, UFS_p3.1, UFS_p4.0

Categories: SST, Nino3.4 · SST, Global Tropics · Prate, Nino 3.4 · T2m, CONUS Land · Z500, NH · Z500, SH · Prate, CONUS Land

Week 3&4 AC Skill Compared with Subx

UFSR2O

Prototypes, normalized by CFSv2 AC

2011-2018
Single runs

CFS_v2 — UFS_p1.0 — UFS_p2.0 — UFS_p3.1 — UFS_p4.0

T2m, CONUS

SubX, normalized by CFSv2 AC

1999-2014
Ensemble runs

GEFS

NCEP_CFSv2 — RSMAS-CCSM4 — ECCC-GEM — EMC-GEFS — NERL_NESM — ESRL_FIMv2 — NASA-GEOS — SubX-MME
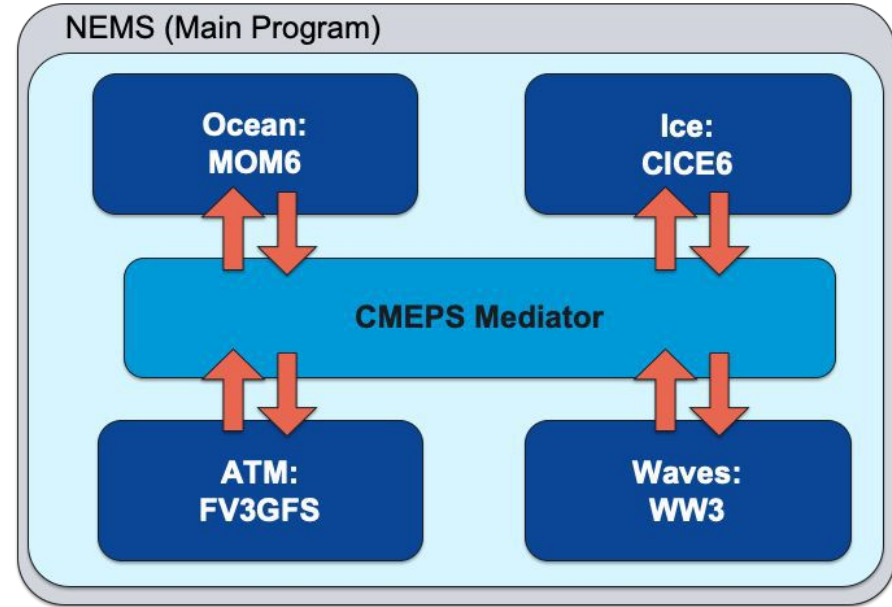
Future Prototypes

- **Prototype 6:**
  - GFSv16 physics with 127L
  - Fractional grid for atm
- **Prototype 7:**
  - Land model
  - GOCART
- **Prototype 8:**
  - Marine DA for IC
  - Physics tuning

NEMS (Main Program)

Ocean: MOM6

Ice: CICE6

CMEPS Mediator

ATM: FV3GFS

Waves: WW3

UFS-R2O Early Results: Global MRW/S2S Application

Physics Sub-Project:

- A complete test plan developed highlighting the use of Thompson Microphysics, RRTMGP, and Unified GWD for MRW/S2S Applications
- Selection of prototype code in the Common Community Physics Package (**CCPP**) for the Global Forecast System (GFS) microphysics scheme
- Specific case selection for process-level evaluation of the convection and PBL schemes in the GFSv16 physics suite using field campaign observations
- Case selection for improving tropical variability (MJO, convectively coupled waves) in the deep convection development focus team.
- Proposed physics upgrades for GFSv17/GEFSv13 are planned.

UFS-R2O Early Results: Global MRW/S2S Application

Atmospheric Composition Sub-Project:

- Develop NASA/NOAA 2nd-generation **GOCART** model connecting NASA GOCART & GEFS-Aerosol

- Include aerosol-radiation interactions in GEFS-Aerosol

- Develop emissions processing system and biomass burning emissions

- Develop quality control and bias correction procedures for AOD used in data assimilation and improve aerosol representation to assist AOD data assimilation

- NASA/NOAA Repository for Next-Gen UFS Aerosol Forecasting (2nd generation GOCART)

- Interlacing physics and chemistry in CCPP version of FV3GFS

UFS-R2O Early Results: Global MRW/S2S Application

Data Assimilation and Reanalysis/Reforecast Sub-Project:

- Progress toward initial public release of **JEDI** software
- Near finalization of DARTH: Document for Acceptance Requirements and Testing of H(x)
- Improved use of observations through UFO development & validation
- Implemented prototype version of **UFS-GODAS** component (JEDI-EWOK transition)
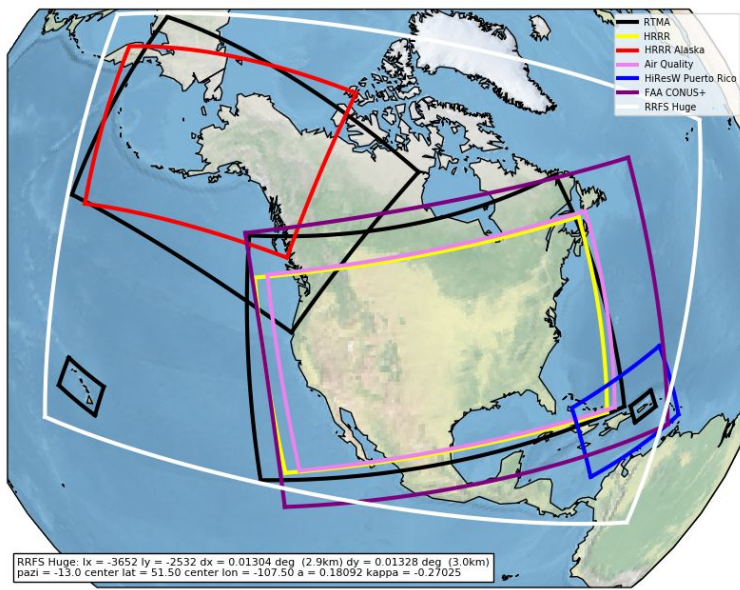- Setup 1 deg UFS model for testing, identified computational bottlenecks in the LETKF solver for the reanalysis
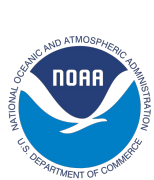
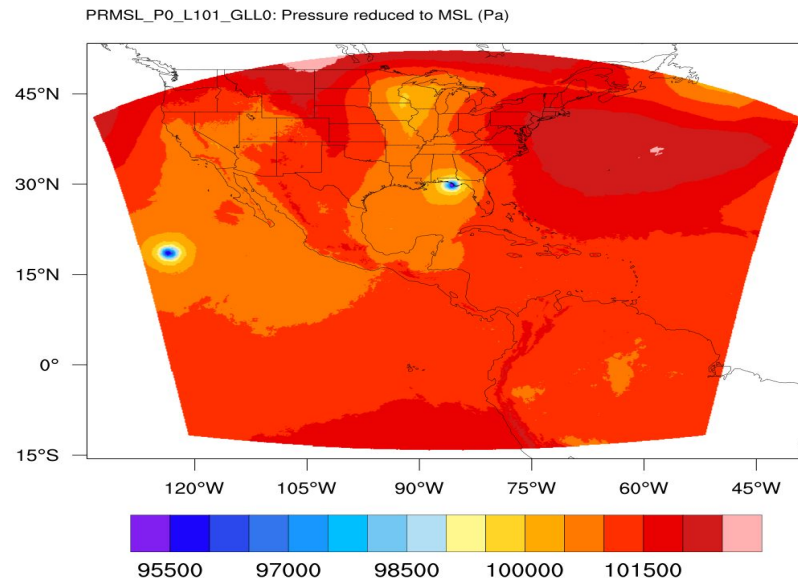# UFS-R2O Project's
Early Results
Regional systems:
Short Range Weather (SRW)
Aka Convection Allowing Models (CAM)
Aka Limited Area Models (LAM)

Regional SRW/CAM Applications

Rapid Refresh Forecast System (RRFS)

Hurricane Analysis and Forecast System (HAFS)

# UFS-R2O Early Results: Regional SRW/CAM Application

RRFS Sub-Project:

- Finalized testing and handed off HREFv3 with FV3-LAM member to NCO for operational implementation

- Selection of physics suite baseline appropriate for high-resolution, using CCPP

- Established FV3 real-time deterministic with GSI-based hybrid/ensemble data assimilation

- Selection of initial set of physics combinations for testing and potential use in multi-physics ensemble. Evaluated some combinations run during HMT FFaIR.

- Convert FV3-LAM (formerly "SAR") model outputs into ABI radiances and perform test and subjective evaluation with 1-2 2020 HWT SFE cases.

UFS-R2O Project's Early Results
## Infrastructure:
Cross-Cutting Infrastructure (CCI)
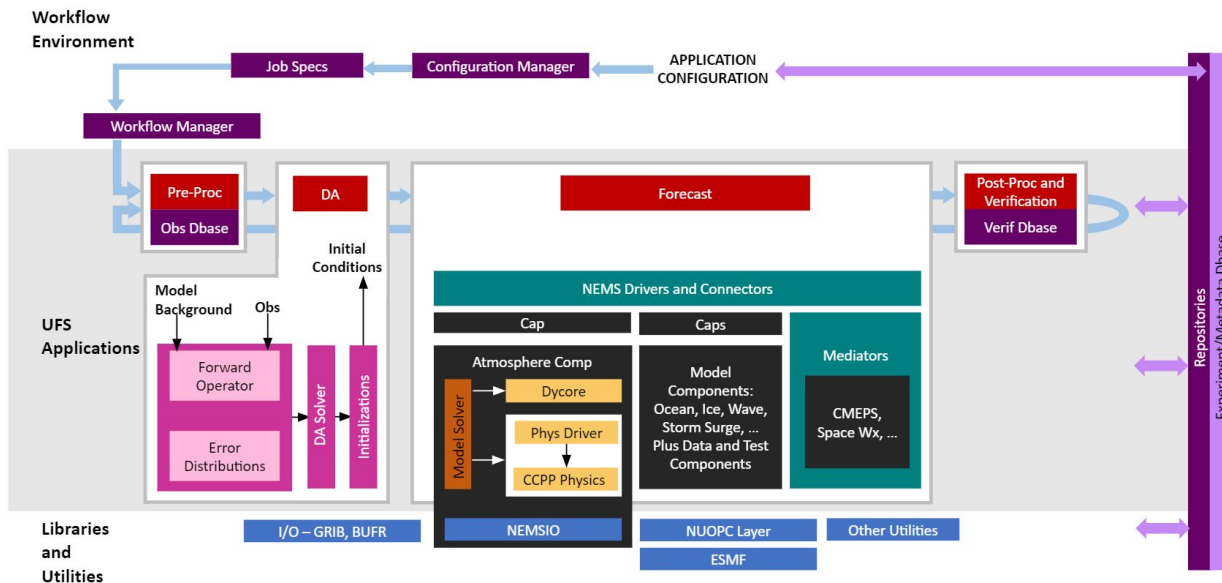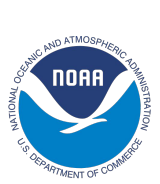
UFS-R2O Early Results: Infrastructure CCI

Modeling Infrastructure:

- Coupling: ESMF v8.1 Release Preparation and User Support (all release items)
- Coupling: CMEPS Development and User Support
- Data Assimilation: JEDI/NUOPC Unified Driver to run free forecast through NUOPC Driver
- Optimization for UFS S2S: including scaling of CMEPS; load balancing; threading; ESMF/NUOPC internal optimizations
- **Github repositories**
  - **Public Release code**
  - **Development code**
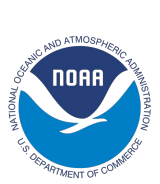
How to get Involved!
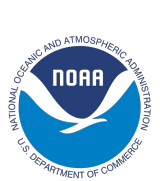
Upcoming UFS Meetings & Events

- **AMS**
  - Two Town Halls: UFS and UFS-R2O Project Town
    - UFS-R2O Project Town Hall will feature larger team, more on regional systems
  - UFS Special Session (**January 11, 2021**)
- **Developmental Testbed Center (DTC) UFS Evaluation Metrics Workshop February 22-24, 2021; (DTCenter.org)**
  Contacts: Tara Jensen (Jensen@ucar.edu), Geoff Manikin (geoffrey.manikin@noaa.gov)
  - **Survey 1** (community inputs on **fields, indices**)
  - **Survey 2** (community inputs on **levels, accumulation intervals, output frequency, validation data sets)**
  - **Survey 3** (community inputs on **process-level diagnostics**, …..)
- **Land modeling workshop - Spring 2021**
 Contact: Maoyi Huang (Maoyi.Huang@noaa.gov)
  - Exploring options for UFS and NOAA's next generation land modeling system

How to Engage with the UFS-R2O Project and UFS Community: UFS Portal, UFS Code, UFS Data

- **AGU Townhall on UFS Community (10-11AM ET, Dec 10)**
    - **UFS Portal (https://ufscommunity.org)**
    - **UFS Webinar**
    - **UFS Public Releases**
    - **UFS Graduate Student Test**
- **UFS Development code on Github**

    https://github.com/ufs-community/ufs-weather-model
- **UFS Data on the Cloud:**
    - UFS S2S prototype run on AWS (POC: Stylianos Flampouris & Avichal Mehra)
    - GFSv16 analysis and forecasts on AWS (POC: Fanglin Yang)
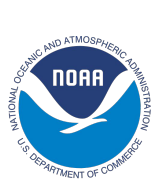
How to Engage with the UFS-R2O Project:
POCs for the UFS-R2O Project

Project Leads: Jeff Whitaker (Jeffrey.s.Whitaker@noaa.gov); Vijay Tallapragada (Vijay.Tallapragada@noaa.gov); Jim Kinter (ikinter@gmu.edu)

Cross-cutting Infrastructure Leads
Modeling:
Rocky Dunlap (dunlap@ucar.edu)
Aun Chawla (Arun.Chawla@noaa.gov)
Verification & Post-processing:
Tara Jensen (jensen@ucar.edu)
Jason Levit (jason.levit@noaa.gov)

SRW/CAM Application Leads:
RRFS: Curtis Alexander (curtis.alexander@noaa.gov)
3DRTMA: Jacob Carley (jacob.carley@noaa.gov)
HAFS: Xuejin Zhang (xuejin.zhang@noaa.gov)

MRW/S2S Application Leads:
Cristiana Stan (cstan@gmu.edu)
Fanglin Yang (Fanglin.Yang@noaa.gov)
Coupled Model Lead: Avichal Mehra (Avichal.Mehra@noaa.gov)
DA, Reanalysis & Reforecast Lead:
Daryl Kleist (daryl.kleist@noaa.gov)
Physics Lead:
Jian-Wen Bao (jian-wen.bao@noaa.gov)
Atmospheric Composition Lead:
Gregory Frost (gregory.j.frost@noaa.gov)

Questions?

For more information:

- **UFS-R2O Project: UFScommunity.org/ufsr2oproject**
  - Dorothy Koch (NWS STI) dorothy.koch@noaa.gov
  - Vijay Tallapragada (NWS EMC) vijay.tallapragada@noaa.gov
- **UFS: UFScommunity.org**
  - Hendrik Tolman (NWS STI) hendrik.tolman@noaa.gov
  - Ricky Rood (U-Michigan) rbrood@umich.edu